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Remote sensing and land suitability analysis to establish local specific inputs for paddy fields in Subang, West Java

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Abstract

Indonesia requires a considerable increase in rice production in the future to keep pace with rapid population growth. Increased production can be done through the specific location-based inputs provision. This study aimed to map land resources in Subang Regency, West Java Province, at a scale of 1:25,000, to evaluate land suitability on any land mapping units and to recommend local specific inputs for paddy fields. The methodology used included land mapping unit delineation, delineation of existing paddy fields using SPOT-6 imagery, soil sampling and laboratory analysis, and land suitability evaluation for the paddy fields. The results showed that in Subang Regency, most paddy fields still allow for intensification through the provision of inputs that are location specific. In the case of the Subang Regency, the local specific inputs include provision of organic matter, provision of lime, provision of N, P and K fertilizer, and construction of irrigation infrastructure. Using the Geographic Information System, the location where the input is necessary can be given in detail. Moreover, beyond the existing paddy field, there are still areas where actual land use is not paddy field but are identified as having potential for the development of paddy fields. As in the case of existing paddy fields, such areas require local specific inputs according to land characteristics that differ from one place to another and can be spatially delineated.

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Keywords: temporal automated land evaluation system; land characteristic; land use and land cover; SPOT-6 imagery

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1. Background

Land and soil have different characteristics from one place to another because in soil, there is a diversity of physical, chemical and biological processes that work spatio-temporally and with varying intensity [1, 2, 3]. With such diverse land characteristics, land utilization for the cultivation of a commodity requires specific input in accordance with its land characteristics. A uniform input provision for diverse land characteristics may cause input shortages in some places, but may cause an excess of input in other places [3, 4]. Inputs that do not match with land characteristics will not be effective and may even become a waste, both in terms of capital input and land resources [5]. In future land resources management, the provision of local specific input needs to be carried out. This local specific input of course is a function of many aspects including land, topography, climate and infrastructure. In fact, crop yield is a complex outcome of many factors including soil, climate and environment [6, 7], and so the input needs to be specified accordingly.

Although soil and land resources characteristics vary from one place to another, the land characteristics can be grouped into more uniform units [8, 9, 10]. In soil mapping, this uniform unit is called the land mapping unit (LMU). Using this concept, land can be said to belong to a unit or to be uniform at a particular map scale. Of course, the uniformity in mapping at a scale of 1:100,000 for example, is different from the uniformity on a map scale of 1:5,000. This uniformity can be used as a basis for the provision of local specific inputs. An input given on a land mapping unit may be different from those given to other land mapping units with different characteristics. In the context of soil and land, land mapping and land resources can be said to be indispensable for agriculture, environment and decision-makers [11]. Research has shown that land characteristics affect soil management behavior [12].

In Indonesia, local specific input has not been widely implemented. Some implementation has been carried out by estate plantation [13] as well as paddy cultivation [14, 15]. In developed countries, provision of local specific inputs in the cultivation has been carried out through precision agriculture [16]. Precision agriculture has good prospects in developing countries [17], but in the case of Indonesia, it appears that the application of this concept is still a struggle, considering the social and economic factors as well as lack of farmers' knowledge. At the farm scale and especially in the cultivation of food crops, local specific implementation is still difficult. There are many factors that influence the adoption of local specific and site-specific technology, including economic aspects [18, 19]. In the case of Indonesia, the difficulty is partly because of the scale of land tenure, which is still very small [14, 20]. As an illustration, the ownership of the average paddy farmer is 0.3 ha [21]. In addition, economic ability and knowledge of farmers are still low, and so it does not allow the application of technology [14]. In such conditions, the input given by the farmers to cultivated land is usually very dependent on economic capabilities and the advice given by the governmental agricultural workers. Therefore, knowledge of agricultural workers and planners in the government for the factors influencing the provision of local specific input is important. In this context, establishing land units in an agricultural area needs to be done. Unfortunately, land mapping in Indonesia has not been thoroughly detailed [22, 23]. However in several areas, the map is already available and so, even when the provision of local specific input cannot be done in detail as in the case of precision agriculture, the land characteristics-based input should be begun. The provision of local specific input on a regency level for example, would be very helpful in the efforts to increase production.

Land resources mapping and land evaluation is one tool that can be used to provide the data for establishing local specific inputs in the context of sustainable agricultural planning [24, 25]. Through soil surveys, a land inventory can be carried out and furthermore, through the process of land evaluation, local specific fertilization advice in accordance with land characteristics can be given.

Since the introduction of the land evaluation concept by the Food and Agriculture Organization [26] and the land capability concept by the US Department of Agriculture [27], the concept of land evaluation has been growing rapidly. Starting with the methods that emphasize the land characteristics and land quality [8, 26], the method was then developed by taking into consideration other aspects including social and economic factors. Examples of this method development can be given through an approach of weighting, for example by using multi-criteria analysis [28, 29].

Paddy fields play an important role in the provision of food in Indonesia, because more than 95% of rice is produced from paddy field production systems [30, 31]. Along with the population growth, the issue of food sovereignty is becoming increasingly complex. In terms of food supply, Indonesia today is faced with complex issues, including the high dependence on the supply of rice from paddy fields in Java Island. The data show that in the year 2014, from the total rice production in Indonesia of 34,172,835 tons, 52.6% was from the paddy fields in Java [32]. Of the total area of paddy fields in Indonesia of 13,835,252 ha [32], there is 6,467,073 ha or 46.7% that is located in Java island,

whereas Java covers only 7% of the land area of Indonesia [33]. Efforts to expand the paddy field area outside Java is continuing, but it is constrained by the limited budget. Inevitably, the current paddy field productivity needs to be improved. Increasing production can be done through many efforts, such as the introduction of the cultivation of high-yield varieties, combating pests and plant diseases, and improving irrigation efficiency. Increasing land productivity can also be achieved by local specific provisions in line with land resources characteristics. In that context, the data of land resources, including the results of the soil survey, can be used for planning production increases.

Increasing production is urgent for Indonesia, given that the level of rice consumption is still high, at 113 kg capita-1 year-1 [33], which is likely to require time to reduce [31]. The challenge of increasing land productivity is not only faced by Indonesia, but also worldwide, as the challenge is how to produce sufficient food for more than 9 billion people by 2050 with land that is increasingly limited. In other, such efforts to increase productivity should remain natural resources sustainable [34, 35, 36, 37].

Within this background, the objective of this research is to present the interpretation of soil maps with their LMUs and land evaluation for planning of increasing rice production through LMU's specific input on existing paddy fields, as well as on the area potentially used for paddy fields.

2. Materials and Methods

2.1. Research area

This study was carried out in the Subang Regency, West Java Province. The regency is geographically located between 107°31'–107°54' East and 6°11'–6°49' South (Fig. 1). The regency has an area of 205,176.9 ha, or 6.4% of the area of West Java Province. The study area is situated at an altitude ranging from 0 to 1500 m above sea level (a.s.l.). Topographically, the area covers three topographic zones [38]. The mountainous zone is located in the south part, has an altitude of 500 to 1500 m a.s.l., and covers 20% of the total area. The hilly zones with a height 50 to 500 m a.s.l. are situated in the middle part of the regency, and cover 35% of the total area. The flat zone, with an altitude of 0-50 m a.s.l., covers 45% of the regency, and is located in the north part; it is situated on the north coast of Java Island and extends to the south part. In the northern part of this region, rice cultivation is mostly done. Topographically, 80% of the study area has a slope of 0-17°, while 10.64% of the area has slopes of 18-45°, and the rest (8.56%) has a slope of more than 45°. Based on the Geological Map of the Subang [39, 40, 41], geological formations in this region include the formation of volcanic rocks from the Pleistocene age in the south part of the region, and the formation of sediments of Neogene and Pleistocene age in the middle part, while the northern part is composed of alluvium formations. The area has a tropical climate, where the average rainfall in 2005 was 2,352 mm/year with the number of rainy days being 100 [38]. Such a climate, supported by the fertile soil, makes most of the area favourable for agriculture.

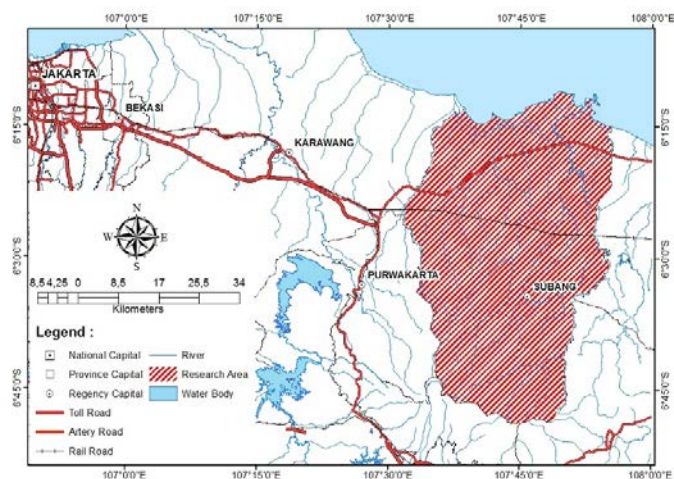


Fig. 1. Research area of Subang Regency, West Java

2.2. *Establishing the land mapping units*

The initial LMU was already available, which is the LMU from a soil map at 1:100,000 [42]. Slope class was derived using the standard Indonesian topographic map at a scale of 1:25,000 produced by Geospatial Information Agency, using the Spatial Analyst module in ArcGIS 10.2 software of the Environmental Systems Research Inc. This slope class was then used for detailing the initial LMU. The result of this process is the soil map at a scale of 1:25,000 with its LMU.

2.3. *Soil sampling and laboratory analysis*

A composite soil sampling was performed on each LMU, taken at a depth of 0-30 cm. Laboratory analysis was performed at the Laboratory of the Dept. of Soil Science and Land Resources, Bogor Agricultural University. In total, 92 soil samples were taken and analysed in the laboratory. The analysis performed was texture (three fractions), pH (H₂O and KCl), Organic Carbon, Total Nitrogen, P₂O₅, K₂O, exchangeable Cations (Ca, Mg, K, Na), Cation Exchange Capacity and Base Saturation.

2.4. *Land use and land cover analysis*

Land use and land cover was delineated using SPOT-6 imagery of 2nd October 2014. A supervised classification was done using ERDAS Imagine software. Field checks were carried out in July 2015. Land use and land cover classification used Indonesian official standard [43]. There are 9 classes of land use/land cover in the study area, however in this paper, special attention is given for paddy field land utilization.

2.5. *Land suitability analysis*

Analysis of land suitability for paddy field was carried out as follows: (i) in the paddy field area delineated by land use and land cover analysis; this analysis was intended to establish the specific input necessary to increase paddy production; and (ii) in the non-paddy field area, this analysis is to examine the possibility of paddy field extension. Land evaluation analysis used the maximum limitation method [26, 44, 45]. Analysis was done using the Automated Land Evaluation System (ALES), according to the method previously described [29, 46, 47]. The criteria used were obtained from the literature [22, 48, 49] and are presented in Table 1. According to this system, the suitability was classified into five classes: S1 (highly suitable), S2 (suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (permanently not suitable). The software used was ALES ver. 4.65e, ArcGIS 10.2, and Microsoft Office. After using ALES for land evaluation, the results were transferred to the ArcGIS for geographical reference to describe the results in the form of maps and tabulation [47, 50].

2.6. *Land status analysis*

The entire analysis of both soil mapping and land suitability was carried out only on the area with forest status that allows for the use of culture, namely an Area for Other Utilization (AOU). To that end, the Map of Forest Areas Status (FAS) at a scale of 1:250,000 of the Planning Agency, Ministry of Forestry [51], was used. Another map taken into account was the Official Spatial Land Use Planning (OSLUP) of Subang Regency 2011-2031 [52]. According to this map, analysis was only done in the area designated for agricultural purposes. In practice, the map of the regency area, the map of FAS and the map of OSLUP were overlaid in GIS in order to find the area that was permitted for agriculture.

Table 1. Criteria used for land suitability evaluation for paddy fields in Subang

Land quality/ Land characteristics	Symbol	Land suitability class				
		S1	S2	S3	N1	N2
Temperature	(t)					
• Annual average (°C)		24-29	>29-32 22-<24	>32-35 18-<22	-	>35 <18
Water availability	(w)					
• Dry month (<75 mm)		<3	3-<9	9-9.5	-	>9.5
• Rainfall (mm)		>1500	1200-1500	800-<1200	-	<800
Rooting media	(r)					
• Soil drainage		poor	poor	medium, well	rapid	very rapid
• Texture ¹⁾		SCL, SiL, Si, CL	SL, L, SiCL, C SiC	LS, Str C	-	S
• Effective depth (cm)		>50	>40-50	>25-40	20-25	<20
Nutrient retention	(f)					
• Cation Exchange Capacity		≥ medium	low	very low	-	-
• Base saturation (%)		>50	35-50	<35	-	-
• Soil pH		>5.5-7.0	>7.0-8.0 4.5-5.5	>8.0-8.5 4.0-<4.5	-	>8.5 <4.0
• Organic-C (%)		>1.5	0.8-1.5	<0.8	-	-
Available nutrient	(n)					
• Total N		≥ medium	low	very low	-	-
• P2O5		≥ high	medium	low-very low	-	-
• K2O		≥ medium	low	very low	-	-
Erosion	(e)					
• Erosion hazard		very low	low	medium	high	very high
• Slope (%)		<3	3-8	>8-15	>15-25	>25

Source: [22, 48, 49]

3. Result and Discussion

Results of the soil and land resources mapping at a scale of 1:25,000 showed that the Subang Regency is divided into 78 LMU. LMU were compiled based on the LMU components that include the soil class (in the sub-group categories according to the USDA soil classification) [53], parent material, slope and landform. Fig. 2 presents the spatial distribution of soil, where map colour is based solely on soil class, while the descriptions of land units are not presented in this paper for clarity reason. A summary of soil class in the category of soil order [53] on land units is presented in Table 2.

Table 2. Main soil order in the LMU

No	Soil	Land Mapping Unit	Area	
			ha	%
1	Aquic Eutrudepts	05a, 06a	14.171,4	6,5
2	Typic Dystrudepts	22a, 22c, 22d, 22e, 24d, 24e, 26a, 26b, 26c, 26d, 36d, 36e, 38b, 38c, 38d, 38e, 38f, 46a, 46c, 46d, 46e, 49c, 49d, 49e, 53d, 53e, 60a, 60c, 60d	49.955,8	23,1
3	Typic Endoaquepts	01a, 10a, 10b, 11a, 11b, 11c, 11d, 11e	75.379,1	34,8
4	Typic Eutrudepts	05b, 05c, 05d, 05e, 06b, 20d, 20e, 27a, 27d, 27e	3.995,4	1,8
5	Typic Haploadox	25c, 25d, 25e, 40c, 40d, 40e, 40f, 56a, 56b, 56c, 56d	19.783,3	9,1
6	Typic Humudepts	42c, 42d, 42e, 42f, 47a, 47d, 47e	6.640,5	3,1
7	Typic Hydraquents	03a	8.242,9	3,8
8	Typic Paleustalfs	12a, 12b, 12c, 12d, 12e, 58a, 58b, 58c, 58d	36.994,2	17,1
9	Typic Udipsamments	04a	1.295,2	0,6
Total			216.457,7	100.00

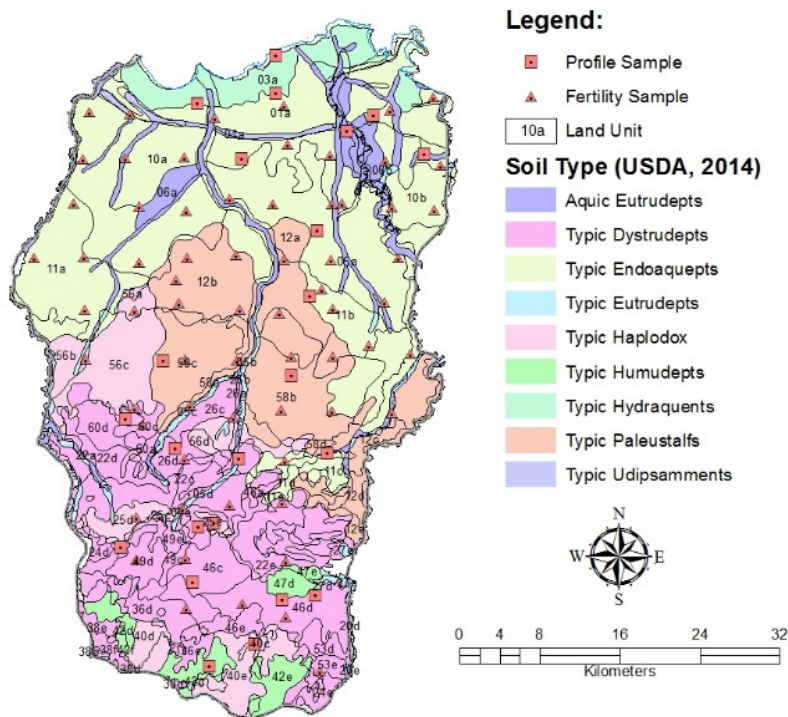


Fig. 2. Soil map, land mapping units and soil sampling in the Subang Regency

In the category of soil order [53], there are four soil orders in Subang, namely Inceptisols, Alfisols, Oxisols and Entisols. The soil order of Inceptisols occupies the largest area, covering 150,142.2 ha or 69.4% of the region. Another soil order that is also quite widespread is Alfisols, which covers 36,994 ha or 17.1% of the area. This dominance of Inceptisols and Alfisols is related to the soil development and local climate [12]. Inceptisols is soil that is relatively young, but has started to develop [53]. In the field, Inceptisols in Subang is generally characterized by the presence of the cambic horizon [53]. Because of its undeveloped phase, generally this soil is relatively fertile. Alfisols in Subang generally has clay accumulation in the subsurface horizon, *i.e.* the so-called argillic horizon [53], which has a high base saturation of more than 35%. The clay accumulation in this horizon comes from the horizon above, which is washed down with water movement [53]. Oxisols occupies an area of 19,783 ha or 9.1%. Oxisols in Subang is old soil, and the easily weathered minerals are low. Its clay content is actually relatively high, but the clay is inactive and so the cation exchange capacity is low (<16 me/100 g clay) [53]. This soil contains a lot of iron oxide or aluminium oxide. In the field, the soil horizon shows diffuse boundaries with each other. Entisols occupies an area of 9,538 ha, or 4.4%. Entisols is a very young soil that is at the beginning of soil development, and is even younger than Inceptisols. In this soil, no horizon identifiers were shown, except ochric, albic or histic epipedons [53]. Field observations and analyses of soil for Entisols in Subang indicate that the epipedons found were ochric or albic.

Imagery used for land use and land cover analysis is presented in Fig. 3a, while the results of the analysis are presented in Fig. 3b and Table 3.

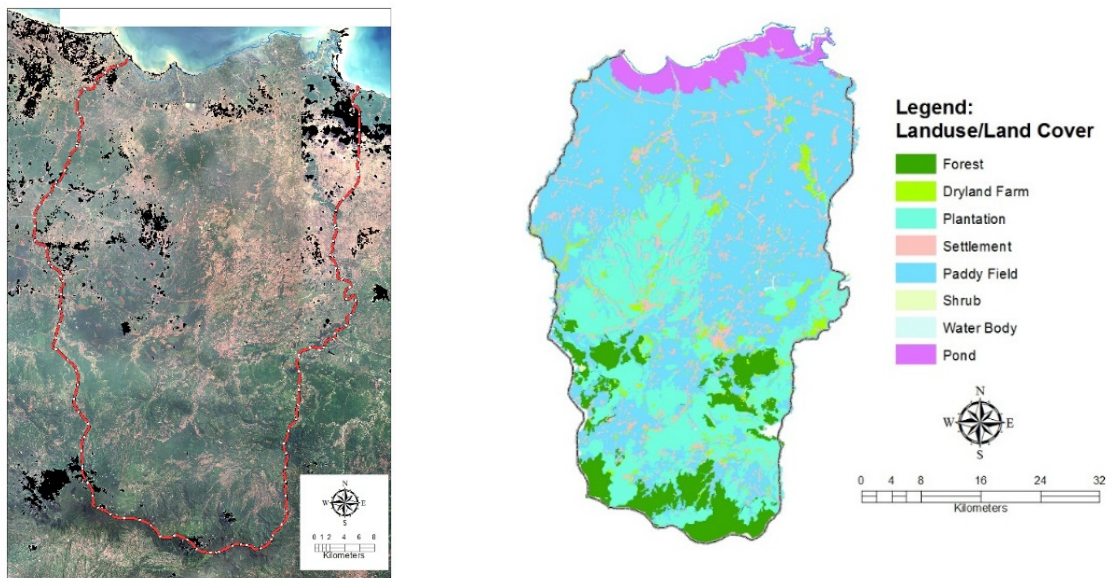


Fig. 3. (a) SPOT-6 imagery acquired on 2nd October 2014; (b) Land use and land cover map of the Subang Regency

Table 3. Land use and land cover of the Subang Regency

No	Land use/land cover	Area	
		ha	%
1	Forest	18,619.6	8.6
2	Fields/"Tegalan"	6,953.6	3.2
3	Estate/Plantations	51,891.8	24.0
4	Settlements	16,229.4	7.5
5	Paddy fields	112,428.3	51.9
6	Shrubs	64.0	0.0
7	River/lake/reservoir/"situ"	779.5	0.4
8	Ponds	8,927.9	4.1
9	Unclassified	563.6	0.3
Total		216,457.7	100.0

The results showed that land use and land cover in the Subang Regency consists of seven kinds of land use/land cover, *i.e.* forest, dry land farms, plantation, paddy field, shrub, pond and water body. In terms of the area coverage, paddy fields and plantations made up the most extensive land use, with 51.9% and 24% of the area, respectively.

According to imagery analysis, the area of paddy fields in the Subang Regency is 112,428 ha. Meanwhile, the statistical data [38] showed that the extent of paddy fields in the Subang Regency is 84,928 ha, which consists of irrigated paddy fields (76,434 ha) and rain-fed paddy fields (8,494 ha). Thus, there is a very significant difference between the image interpretation and statistical data, the difference is 27,500 ha. The difference is likely due to differences in the measurement accuracy and methods, which has also been found in previous studies [54]. Remote-sensing techniques are very useful for the detection of paddy fields. However, the level of accuracy of this analysis is, on average, 89.4%. With increasing steep slopes, paddy field deviation detection will be higher [54, 55]. In this study, the agreement of image interpretation results with statistical data only amounted to 75.5%, which is very low when compared with previous studies that reached >95% [54]. Regardless of the level of accuracy, the next discussion in this paper will use the data from the imagery analysis.

According to the FAS map, the Subang Regency has a forest area covering 29,958 ha, which is 13.8% of the total area of the Subang Regency. The forest areas consist of protected forest (7,267 ha, or 3.4% of the area), preserved and tourism forest (1,586 ha, or 0.7% of the Subang area), production forest (17,949 ha or 8.3% of the Subang area), and limited production forest (3,126 ha or 1.4% of the Subang area). The rest is the area with AOU status, which allows

it to be used for cultivation and agriculture, including paddy fields. In this paper, the paddy fields that were analysed were those lying in the AOU.

A summary of the results of laboratory analysis is presented in [56], they are presented spatially in Fig. 4 according to geostatistical distribution [57, 58]. Based on the results of the laboratory analysis, the actual land suitability in existing paddy fields is presented in Fig. 5a, while the covering areas of various suitability classes are presented in Table 4. The results show that the area with land suitability of S1 (highly suitable) for paddy fields covers 82.3 ha, or only 0.1% of the existing paddy fields. The area with actual land suitability for paddy fields of S2 (suitable) is the majority, and accounts for 96,906.5 ha or 86.3% of the existing paddy field area. The limiting factors that led to S2 land suitability include land quality of rooting media (r), nutrients available (f), nutrient retention (n) and water availability (w), either individually or in combination. The limiting factor of rooting media (r) consists of several land characteristics as limiting factors, *i.e.* soil drainage, effective depth and soil texture. In the case of the Subang Regency, the major limiting factor is soil texture, while soil drainage and effective depth were not serious limiting factors. In most of Subang, the majority of the soil consists of Inceptisol and Alfisol, which generally have sufficient depth. Conversely, the soil texture in some soil samples indicates the range of soil texture from loam, sandy clay loam to sandy loam. Such rough soil texture could become a barrier to the efficiency of water availability for paddy fields. The land quality of nutrient availability (f) which became a limiting factor consists of several land characteristics, *i.e.* soil cation exchange capacity (CEC), base saturation, soil pH and organic-C (%). Of these four land characteristics, there are only three that become a major barrier: CEC, base saturation and soil pH.

There are only a few soils in Subang where the organic-C becomes a limiting factor for paddy fields. The value of CEC of the soil samples taken ranged from very low to high when they are classified based on the assessment criteria of soil chemical properties [22]. The lowest value of CEC of the samples was 1.10 me/100 g (very low), while the highest value was 131.5 me/100 g (very high). The value of organic-C of the samples ranged from 0.1% (very low) to 9.25% (very high). Limiting factors of nutrient retention (n) include land characteristics of total-N, P_2O_5 and K_2O . These three land characteristics may become limiting factors for soil in Subang. Nevertheless, it can be stated that the nitrogen is a major limiting factor. The value of P_2O_5 of the samples ranged from 0 to 210 ppm (very high). The value of total-N ranged from 0.07% (very low) to 0.67% (high). The value of K_2O of soil in Subang ranged from 0 to 630 mg/100 g (very high). The land quality water availability (w) consists of the land characteristics of precipitation and the number of dry months. However, the land characteristic that arises as a limiting factor in Subang is rainfall, while the number of dry months is not a limiting factor. The climate in Subang is relatively wet. When classifying the number of dry (<75 mm rain) months [22], there are 2-3 dry months and so this is not a limiting factor. Conversely, rainfall can become a limiting factor, especially in the northern part of the region, which has rainfall of between 800 and 1200 mm.

The area with the actual land suitability of S3 (marginally suitable) for paddy fields was 15,439.6 ha or 13.8% of the area of the Subang Regency. The land quality that emerges as limiting factors is rooting media (r), available nutrients (f), nutrient retention (n) and slope (s). Land characteristics that emerged from each land quality are generally the same as the land characteristics that appear to become limiting factors for the S2 class, but with higher limiting intensity. The land characteristic of slope appears as a limiting factor in the area of rain-fed paddy fields, which in some cases are on a relatively steep slope (8-15%). For irrigated paddy fields, slope is not a limiting factor. In actual paddy field, when the slope is steep slopes, bunds and terraces have generally been made, and so erosion is relatively small.

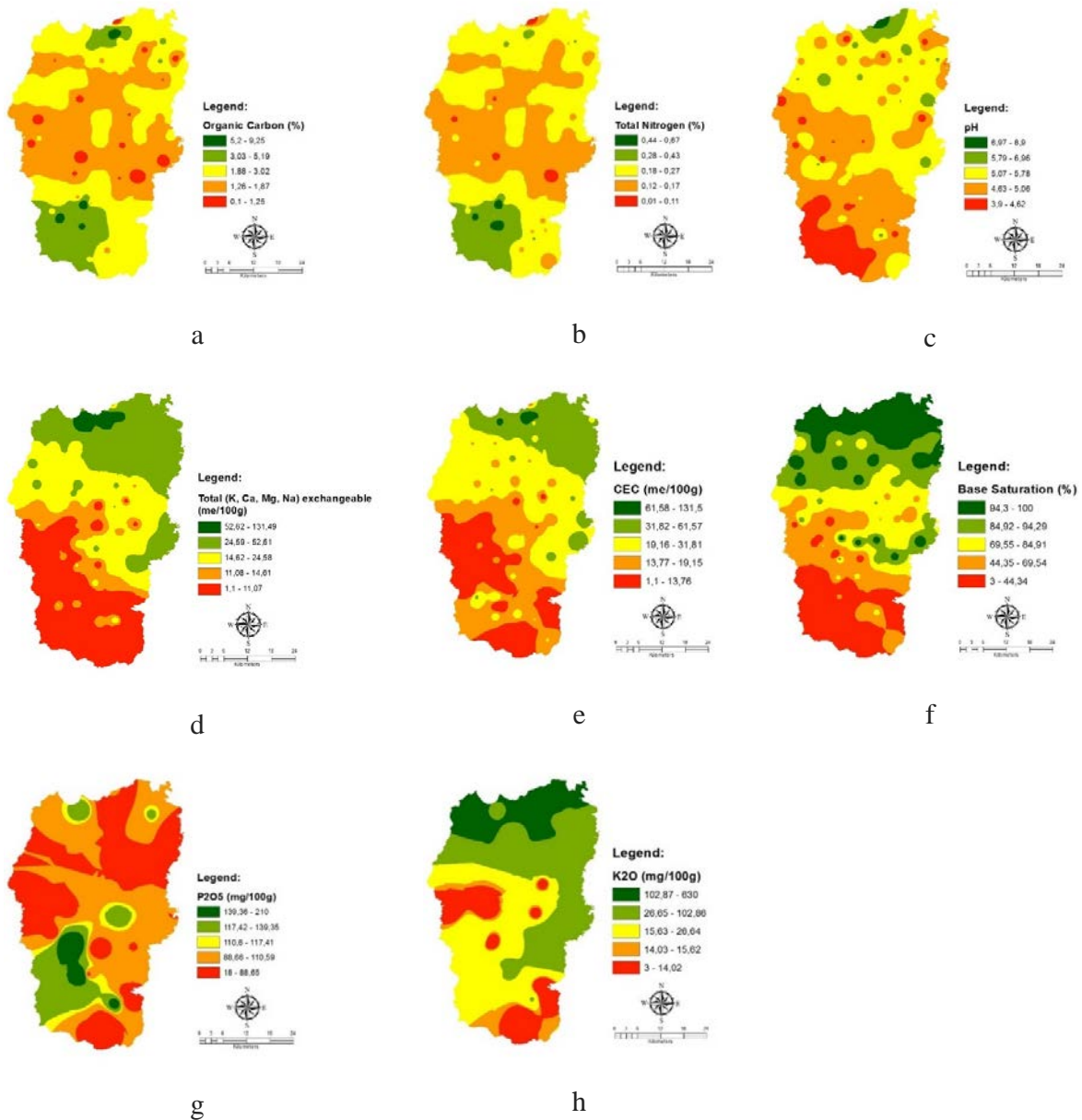


Fig. 4. Map of: (a) Soil Organic Carbon, (b) Total Nitrogen; (c) pH; (d) Exchangeable (K, Ca, Mg, Na); (e) CEC; (f) Base Saturation; (g) P₂O₅; and (h) K₂O

For some of the limiting factors, improvement cannot be done or at least cannot be done at a farm scale. One example of such a limiting factor is rooting media (r), which is caused by soil texture. Some other limiting factors can be improved, *e.g.* available nutrients which can be improved with fertilizer input. Although conceptually soil texture cannot be improved, organic matter can be added, which serves to improve soil structure and so it can give a better environment for plant roots. The limiting factor of nutrient retention (f) in Subang, which is caused by low cation exchange capacity and low soil pH, can be improved through the provision of organic matter to increase the soil capacity to hold nutrients and liming to increase the soil pH. Limiting factors of available nutrients (n) can be improved mainly through the provision of N, P and K fertilizers. Such improvement efforts can be expressed as the provision of

specific location inputs in paddy fields. Because the provision of inputs is based on the land characteristics that become limiting factors on any LMU, it can be called a LMU-based specific input. With the improvement, actual land suitability classes can be upgraded into the potential land suitability class. Actual and potential land suitability maps on existing paddy fields in the Subang Regency are presented in Fig. 5a and 5b.

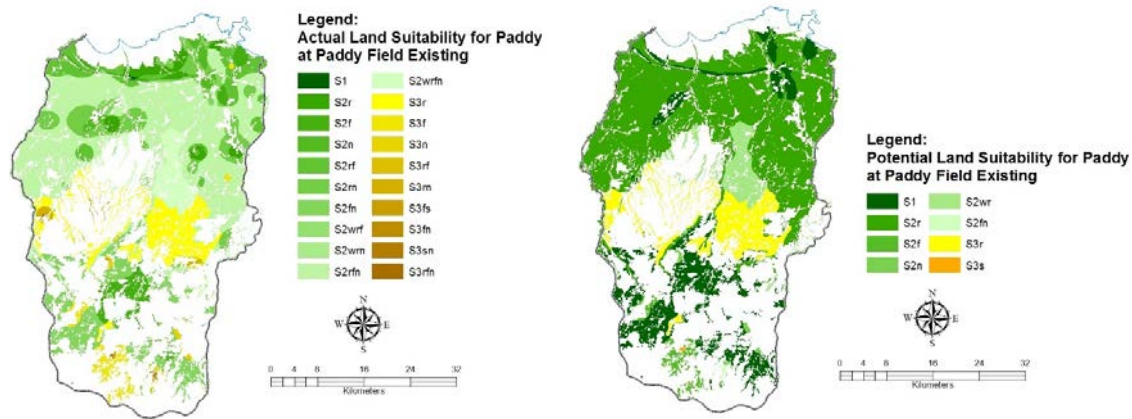


Fig. 5. Map of: (a) actual land suitability, and (b) potential land suitability, for paddy fields in the existing paddy field area of the Subang Regency. Limiting factor code [22]: w = water availability, r = rooting media, f = available nutrients, n = nutrients retention, s = slope

Table 4. Land suitability for paddy fields in existing paddy fields and specific location inputs necessary

No.	Land suitability	Land mapping unit	Specific location input	Area	
				ha	%
1	S1	03a, 04a, 46d	-	82.3	0.1
2	S2r	01a, 05a, 10a, 11a	Provision of organic matter for improvement of soil structuration	3,966.9	3.5
3	S2f	03a, 04a, 05d, 05e, 06a, 06b, 11d, 22a, 22c, 22d, 22e, 25c, 25d, 25e, 26a, 26c, 26d, 46c, 46d, 46e, 47d, 49d, 49e	Liming for improvement of soil acidity	4,973.7	4.4
4	S2n	03a, 04a, 06a, 46d, 47d	N, P and K fertilizing for improvement of available nutrients	1,838.9	1.6
5	S2rf	01a, 05a, 05b, 10a, 10b, 11a, 11b	Liming for improvement of soil acidity and provision of organic matter for improvement of soil structuration	8,399.9	7.5
6	S2m	01a, 05a, 05b, 10a, 10b, 11a, 11b	Provision of organic matter for improvement of soil structuration and liming for improvement of soil acidity	9,545.4	8.5
7	S2fn	03a, 04a, 05d, 05e, 06a, 11c, 11d, 11e, 12d, 12e, 20d, 20e, 22a, 22c, 22d, 22e, 24d, 24e, 25c, 25d, 25e, 26a, 26b, 26c, 26d, 27a, 27e, 36d, 36e, 38e, 38f, 40c, 40d, 40e, 42c, 42d, 42e, 46a, 46c, 46d, 46e, 47d, 47e, 49d, 49e, 53d, 53e, 56d, 58d, 60d	Liming for improvement of soil acidity and N, P and K fertilizing for improvement of available nutrients	13,665.4	12.2
8	S2wrf	12a, 12b	Liming for improvement of soil acidity and provision of organic matter for improvement of soil structuration	150.2	0.1
9	S2wrn	12a, 12b, 12c	Provision of organic matter for improvement of soil structuration and liming for improvement of soil acidity	332.7	0.3
10	S2rfn	01a, 05a, 05b, 05c, 10a, 10b, 11a, 11b	Liming for improvement of soil acidity, provision of organic matter for improvement of soil structuration and N, P and K fertilizing for improvement of available nutrients	46,989.2	41.8

No.	Land suitability	Land mapping unit	Specific location input	Area	
				ha	%
11	S2wrfn	12a, 12b, 12c	Liming for improvement of soil acidity, provision of organic matter for improvement of soil structuration and N, P and K fertilizing for improvement of available nutrients	7,044.2	6.3
12	S3r	49c, 56a, 56b, 56c, 58a, 58b, 58c, 60a, 60c	Provision of organic matter for improvement of soil structuration	11,353.5	10.1
13	S3f	01a, 05a, 10a, 11a, 24d, 25c, 25d, 36d, 36e, 38c, 38e, 40c, 40d, 40e, 42c, 42d, 42e, 46c, 46d, 46e, 49d	Liming for improvement of soil acidity	2,317.4	2.1
14	S3n	01a, 05a, 05b, 05c, 05d, 11a, 11c, 11d, 26c, 26d, 40c, 40d, 40e, 42c, 42e, 46c, 46d, 46e, 47d, 47e, 58d	N, P and K fertilizing for improvement of available nutrients	791.8	0.7
15	S3rf	56b, 56c	Liming for improvement of soil acidity and provision of organic matter for improvement of soil structuration	28.7	0.0
16	S3rn	56b, 56c, 58a, 58c	Provision of organic matter for improvement of soil structuration and liming for improvement of soil acidity	688.7	0.6
17	S3fn	05b, 26c, 26d, 40c, 40e, 42c, 42e, 46c, 47e	Liming for improvement of soil acidity and N, P and K fertilizing for improvement of available nutrients	152.9	0.1
18	S3fs	46d	Liming for improvement of soil acidity, bunds and terraces in rain-fed paddy fields	39.4	0.0
19	S3sn	36d	N, P and K fertilizing for improvement of available nutrients and bunds and terraces in rain-fed paddy fields	27.9	0.0
20	S3rfn	56b, 58c	Liming for improvement of soil acidity, provision of organic matter for improvement of soil structuration and N, P and K fertilizing for improvement of available nutrients	39.3	0.0
Total				112,428.3	100.0

Table 5. Land suitability for paddy fields in non-paddy field area in the Subang Regency

No	Land suitability	Land mapping unit	Specific location input	Area	
				ha	%
1	S2r	01a, 05a, 10a, 11a	Provision of organic matter for improvement of soil structuration	135.9	3.0
2	S2rf	01a, 05a, 10a, 10b, 11a, 11b	Provision of organic matter for improvement of soil structuration, liming for improvement of soil acidity	87.0	1.9
3	S2rn	01a, 05a, 05b, 10a, 10b, 11a, 11b	Provision of organic matter for improvement of soil structuration, N, P and K fertilizing for improvement of available nutrients	666.7	14.5
4	S2fn	27a	Liming for improvement of soil acidity, N, P and K fertilizing for improvement of available nutrients	11.2	0.2
5	S2wrn	12a, 12b, 12c	Provision of organic matter for improvement of soil structuration	372.8	8.1
6	S2rfn	01a, 05a, 05b, 05c, 10a, 10b, 11a, 11b	Provision of organic matter for improvement of soil structuration, liming for improvement of soil acidity, N, P and K fertilizing for improvement of available nutrients	1,715.6	37.3
7	S2wrfn	12a, 12b, 12c	Provision of organic matter for improvement of soil structuration, liming for improvement of soil acidity, N, P and K fertilizing for improvement of available nutrients	479.9	10.4
8	S3r	49c, 56a, 56b, 56c, 58a, 58b, 58c, 60a, 60c	Provision of organic matter for improvement of soil structuration	1,016.7	22.1
9	S3f	05a, 10a	Liming for improvement of soil acidity	0.7	0.0
10	S3n	05a, 05b, 11a	N, P and K fertilizing for improvement of available nutrients	7.3	0.2
11	S3rf	56b, 56c, 60c	Provision of organic matter for improvement of soil structuration, liming for improvement of soil acidity	6.0	0.1
12	S3rn	56b, 56c, 58a, 58c	Provision of organic matter for improvement of soil structuration, N, P and K fertilizing for improvement of available nutrients	98.6	2.1
13	S3fn	05b	Liming for improvement of soil acidity, N, P and K fertilizing for improvement of available nutrients	0.0	0.0

No	Land suitability	Land mapping unit	Specific location input	Area	
				ha	%
14	S3rfn	56b	Provision of organic matter for improvement of soil structuration, liming for improvement of soil acidity, N, P and K fertilizing for improvement of available nutrients	6.8	0.1
Total				4,605.3	100.00

This analysis can be continued to see the potential of land where paddy fields can be constructed. Land suitability analysis results in a non-paddy fields area that are considered potential shows that the main limiting factors include rooting media (r), nutrient retention (f), available nutrients (n) and water availability (w). The treatment assumed for increasing the actual land suitability to potential land suitability includes organic matter and N, P, and K fertilizer. This input is intended to improve nutrient retention and available nutrients. In addition to the increase in potential based on the existing limiting factors, one improvement in non-paddy fields, of course, is the construction of irrigation channels (Fig. 6).

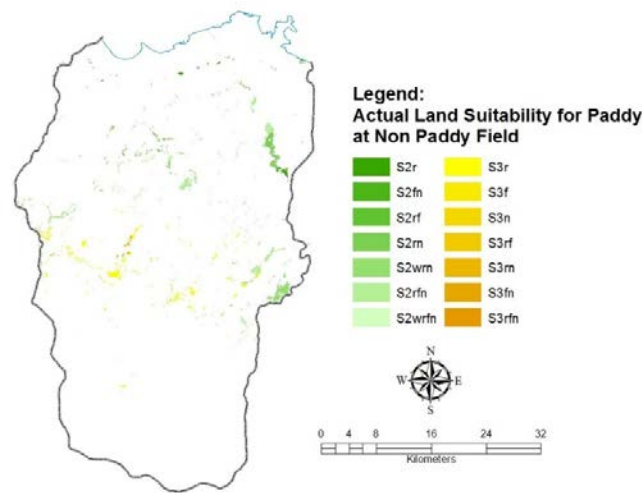


Fig. 6. Map of actual land suitability for paddy fields in the non-paddy field area in Subang

The subject presented above is principally the utilization of a land resources map with a uniform land unit. Such map can further detailed with local specific provision. The dose for each treatment is not presented in this paper, as it will need more detailed research. Further studies should be done to obtain appropriate provisions according to specific land characteristics. General suggested provisions have been given [59], which has been developed as guidelines. The guidelines are still based on administrative zoning, and so it became a more general overview. It will be very helpful if, in the future, such guidelines could be made taking into consideration the land characteristics.

4. Conclusion

The analysis done in this paper shows that the soil and land resources data, integrated with the remotely sensed data and land evaluation, can be interpreted as planning for local specific inputs based on land characteristics in the context of increasing rice production.

In Subang Regency, most paddy fields still allow for intensification through the provision of inputs that are local specific. The provision of local specific inputs was done to overcome limiting factors that can be identified through the land suitability analysis. In the case of Subang Regency, the local specific inputs include provision of organic matter, provision of liming, provision of N, P and K fertilizer, and construction of irrigation infrastructure. Using the GIS, the location where the input is necessary can be given in detail.

Moreover, beyond the existing paddy fields, although not too extensive and in a sufficiently wide area, there are still areas where the actual land cover is not paddy fields, but are identified as having the potential for the development

of paddy fields. As in the case of existing paddy fields, such areas also require local specific inputs that differ from one place to another and can be spatially delineated. This information, which is accompanied by spatial information, can be used as a reference for detailed planning of increasing rice production. This research should be followed by more detailed planning, including the precise doses for paddy fields.

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